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Multistage biological contact oxidation for landfill leachate treatment: Optimization and bacteria community analysis

Chunli Yuan [a,1], Youzhao Wang [a,1], Tong Zhu [a,*], Xuelin Feng [a], Yongguang Ma [a,b], Fenghao Yu [c], Yuanhua Xie [a]

[a] School of Mechanical Engineering and Automation, Northeastern University, 3-11, Wenhua Road, Heping District, Shenyang 110004, China
[b] Liaoning Provincial Machinery Research Institute Co. Ltd., No.56 Beijing Street, Huanggu District, Shenyang City, Liaoning Province, China
[c] Ansteel Engineering Technology Co. Ltd., China

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ABSTRACT

Landfill leachate is a wastewater contained solid waste and is hard to treat due to its complex composition. The most effective treatment is biological method among leachate transfer, biological treatment, and physical and chemical methods, however, the chemical oxygen demand (COD) removal efficiency of present biological treatment has not been more than 90% at influent COD concentration of 2000 mg/L to 5000 mg/L. In this study, the multistage biological contact oxidation (MBCO) is performed for treating landfill leachate. The optimized parameters as followed achieve 91.28% COD removal efficiency: influent COD landfill leachate concentration of 4000 mg/L; 0.1 L/min·L (reactor volume) aeration rate; temperature (T) of 35 °C and hydraulic retention time (HRT) of 24 h and also obtained 318.64 mg/L ammonium nitrogen (NH_3-N) effluent concentration, Besides, biofilm community structure show that *Proteobacteria*, *Bacteroidetes* and *Firmicutes* are identified as the dominant in phylum. All the results indicate that the MBCO is an effective technology for landfill leachate treatment.

1. Introduction

Landfill leachate is a kind of refractory wastewater that is deposited solid waste stored in a leachate, also generated by rainfall and groundwater which percolate through the waste layers (Zhang et al., 2013). This landfill leachate generally contains a variety of pollutants, which include a very high level of organics, ammonia, heavy metals, microorganisms as well as soluble mineral substances (Xie et al., 2010). Due to these pollution to the environment, landfill leachate must be properly treated to remove amount of organic matters (measured as chemical oxygen demand (COD)) and ammonium nitrogen (NH_3-N) before it is discharged into the environmental water bodies. Therefore, leachate treatment is critical to be selected for removing pollutants.

A variety of landfill leachate treatments can be divided into three major methods: leachate transfer (Zhao et al., 2013), biological treatment, and physical and chemical methods (Uygur and Kargı, 2004). Among the leachate transfer methods, the leachate combine treatment with domestic sewage. This method is low cost and easy to main, however, its treatment efficiency is low. Physical and chemical methods include flotation, coagulation, chemical precipitation, adsorption, chemical oxidation, and membrane process (microfiltration, ultrafiltration, nanofiltration and reverse osmosis) (Wiszniowski et al., 2006) (Renou et al., 2008). Chemical method has high efficiency and also high cost. Physical treatment has not been effective on organic removal. At present, biological methods used for landfill leachate treatment, are anaerobic method (Mnif et al., 2012) and aerobic treatments (Xie et al., 2014) (Ismail and Tawfik, 2016). And also they have been taken into account to be effective in removing organics and nitrogenous matters. However, COD removal efficiency of present biological treatment is less than 90%.

This objective of this study is to present a novel multistage biological contact oxidation (MBCO) method for removing organics in landfill leachate. The performance of effluent concentration and removal efficiency of COD and NH_3-N were studied in the start-up and experimental operation. Four factors included influent COD concentration, aeration rate, temperature (T) and hydraulic retention time (HRT) were optimized by orthogonal experiment to

* Corresponding author.
E-mail address: tongzhu@mail.neu.edu.cn (T. Zhu).
[1] These authors contributed equally to this work and should be considered co-first authors.

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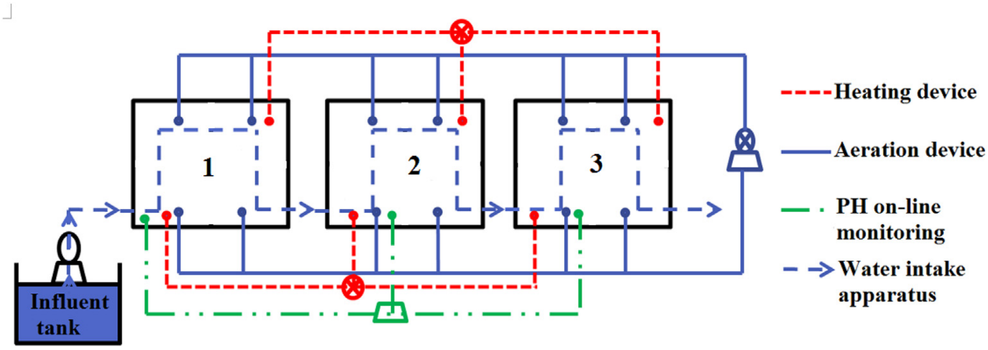

Fig. 1. Schematic diagram of reactor structure.

achieve the highest COD removal efficiency. In addition, for better understanding of the bacteria structure in landfill leachate, the bacteria community structure of phylum and genus levels were investigated at 2000 and 5000 mg/L landfill leachate concentrations.

2. Materials and methods

2.1. Experimental equipment

Schematic diagram of experimental equipment was shown in Fig. 1. The MBCO reactor was made of three chambers which had working volume of 90 L. Every chamber was laid by the filler frame made of soft fiber filler. Aeration provided by air blower and controlled by an aeration valve with flow rate of 140 L/min to ensure sufficient dissolved oxygen (DO). The heating device was a heating rod. The PH on-line monitoring device comprised a PH probe, control instrument and fluid infusion pump. The water intake apparatus contained a peristaltic pump which extracted water from bucket and a wave pump with stirring effect.

2.2. Materials

Landfill leachate samples were collected from Shenyang Tiger landfill site. The influent wastewater is a mixture of synthetic wastewater and landfill leachate in varying ratios to start up the system. The composition information of influent wastewater was shown in Table S1 of supplementary materials.

Seed sludge consisted of aerobic activated sludge in the first chamber and mixed sludge with denitrification characteristics in the second and third chamber. Aerobic activated sludge was collected from Shenyang, China. The mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) concentrations of the aerobic activated sludge were 5.4 g/L and 3.8 g/L, respectively. The mixed sludge with denitrification was artificially cultivated in the laboratory. MLSS and MLVSS concentrations of the mixed sludge with denitrification were 34.2 g/L and 29.5 g/L, respectively.

2.3. Analytical methods

The analyses of chemical oxygen (COD), MLSS, MLVSS and NH_3-N were determined according to Standard Methods (APHA, 1998). The pH was measured with a PHSJ-4F pH-meter (Shanghai Yidian).

The bacterial community structure was analyzed using agarose gel electrophoresis in Illumina sequencing platform. Bacteria abundance was quantified by PCR. The primer sets 338F (ACTCC-TACGGGAGGCAGCAG) and 806R (GGACTACHVGGGTWTCTAAT) were used to target all bacteria.

Table 1
The orthogonal design and analysis on COD.

Experiment	A Influent COD (mg/L)	B Aeration rate (L/(min))	C T (°C)	D HRT (h)	COD removal efficiency (%)	COD effluent concentration (mg/L)
1	5000	12	25	18	85.79	707.99
2	5000	9	30	24	85.19	748.16
3	5000	6	35	36	89.48	520.55
4	4000	12	30	36	90.51	374.48
5	4000	9	35	18	88.28	471.31
6	4000	6	25	24	84.74	592.05
7	3000	12	35	24	88.93	332.96
8	3000	9	25	36	84.88	454.82
9	3000	6	30	18	84.26	468.2
$\overline{K}_{i1}^{a}$	86.820	88.410	85.137	86.110		
$\overline{K}_{i2}$	87.843	86.117	86.653	86.287		
$\overline{K}_{i3}$	86.023	86.160	88.897	88.290		
R	1.820	2.293	3.760	2.180		
$\overline{k}_{i2}^{b}$	658.900	471.810	584.953	549.167		
$\overline{k}_{i2}$	479.280	558.097	530.280	557.723		
$\overline{k}_{i3}$	418.660	526.933	441.607	449.950		
r	240.240	86.287	143.346	107.773		

$\overline{K}_{ij}^{a}$ means the horizontal average value of a factor on COD removal efficiency (i = A,B,C and D represents the factors name; j = 1,2 and 3 represents factors level); $\overline{k}_{ij}^{b}$ means the horizontal average value of a factor on effluent COD concentration; R is the range of each column on COD removal. r is the range of each column oneffluent COD concentration.